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Aircraft Fire Detection: Requirements, Qualification and Certification Aspects

1. Abstract

For aircraft applications other or additional qualification requirements need to be fulfilled by the automatic fire detection instrument compared to those applicable to buildings. It is important to distinguish between pressurized zones and non pressurized zones due to their completely different environments (e.g. inside/outside temperature and pressure/altitude).

This paper will concentrate on fire detection aspects applicable to pressurized areas of transport aircraft where passengers and cargo are located.

2. Introduction

For some aircraft compartments a fire/smoke detection system is required by the regulations JAR[1].and/or FAA[2]. For example:

JAR/FAR 25.854 requires the installation of a smoke detector system or equivalent for each lavatory.

JAR/FAR 25.857 requires the installation of a separate approved smoke detector or fire detector system for some cargo compartments.

JAR/FAR 25.858 defines details for cargo compt fire detection systems.

In addition, aircraft manufacturers install supplementary fire/smoke detection systems to increase the level of safety. These systems must comply e.g. with subsequent regulations.

JAR/FAR 25.1301 Function and Installation:

Each item of equipment must

(a) Be of a kind and design appropriate to its intended function

(b) Function properly if installed

Additional systems are installed in Airbus aircrafts to monitor areas which are not permanently occupied or monitored by crew members or passengers like

- Main avionics compartment (computer room / electrical energy center)
- Customized electronics equipment bays (e.g. In - Flight Entertainment)
- Crew rest compartments / lower deck facilities

The urgency of the corrective action subsequent to a fire/smoke warning depends directly on the risk and is reflected in the procedure to be applied by cockpit or cabin crew.

For example, a cargo compt smoke warning will be indicated to the flight deck crew as a red warning, this means the crew has to perform the action immediately.

In this case the

- air ventilation system, if any, needs to be turned off and associated compartment isolation valves have to be closed
- fire extinguishing system needs to be activated
- crew has to land the aircraft as soon as possible, etc

As long as the crew is unable to differentiate between a true and a false warning, it has to follow the certified procedure.

The impact of a false fire/smoke warning in non accessible compartments is extensive and might include: flight diversion, declaration of emergency situation, eventually passenger evacuation, compartment inspection, fire extinguisher replacement, customer/passenger disappointment, loss of confidence in the warning system etc.

To minimize the risk, an early detection of an in-flight fire/smoke situation is mandatory to initiate the corrective action at an appropriate time. On the other hand, false/unconfirmed warnings could be critical as well.

With the 60 seconds detection time requirement as addressed in JAR/FAR 25.858 (a), the system design is always a compromise between fast detection and warning signal reliability.

This time was originally assigned to cargo compartment applications and has often been required/applied by airworthiness authorities [3] and/or system designers to in flight inaccessible compartments or remote located crew rest rooms.

3. Fire Detection Requirement (JAR/FAR 25.858)

If certification with cargo compartment fire detection provisions is requested, the following must be met for each cargo compartment with those provisions:

(a) The detection system must provide a visual indication to the flight crew within one minute after the start of the fire.

(b) The system must be capable of detecting a fire of a temperature significantly below that at which the structural integrity of the aeroplane is substantially decreased.

(c) There must be means to allow the crew to check, in flight, the functioning of each fire detection circuit.

(d) The effectiveness of the detection system must be shown for all approved configurations and conditions.

4. Experience

An analysis of false warning scenarios identified the following main problem areas:

- sensitivity to aircraft environmental condition changes (temperature, pressure / altitude, humidity, power transients, electromagnetic interference, exhaust fumes from ground loading equipment etc)
- insufficient knowledge of either sensor/detector functions by aircraft manufacturers or specific to type aircraft environmental conditions by fire/smoke detector instrument manufacturers
- detector/sensor stability
- sensitivity to cargo/load transported in the compartment
- sensitivity to sprays used in lavatories
- insufficient detector cleaning (operator and/or interval)

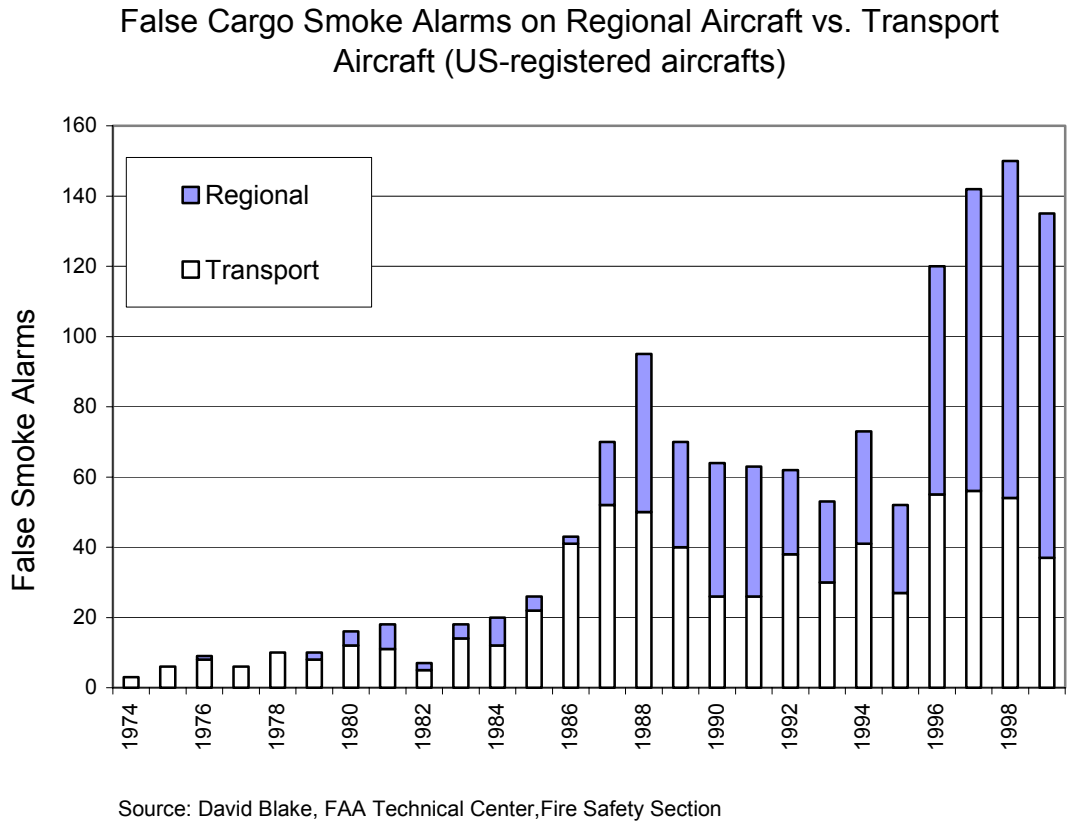
- penetration of unexpected particles (contaminated/unfiltered air) into the measurement measurement chamber(s)
- detectors evaluation (open-area /point type or flow-through /duct type)
- single detector alarm dependence

From the a.m. items we can identify the two main areas of possible improvements. The fire/smoke detector itself, and the associated integration into the aircraft. The integration in the aircraft specific environment and the need to customize specific to type solutions is a real issue which makes it difficult to standardize detectors for the various aircrafts and applications.

We, at Airbus Industries consider the minimum requirements for fire/smoke detection instruments as defined in standard JTSO/TSO-C1c [4] as not sufficient as far as fire/smoke detection performances and warning reliability is concerned.

In considerisation of this, EADS-Airbus uses aircraft specific integration guidelines and purchases smoke detectors/systems according to own detailed technical specifications. In addition new detection technologies are closely monitored by system design office [5].

The following graphic shows the occurrences of false smoke warnings in cargo compartments of US-registered aircrafts within the last 25 years [6]. Of course air traffic increased and the requirements to install smoke detection systems have been amended. Therefore the general increase of false warnings per year could be explained.



Source: David Blake, FAA Technical Center,Fire Safety Section

If we investigate in the a.m. graphic the share between regional aircrafts and transport aircrafts, we can conclude that the efforts spent by transport aircraft manufactures in the last years to reduce the rate of false warnings were efficient considering that the number of installations increased whereas the occurrence of false cargo smoke warnings maintained nearly the same level or decreased.

We are convinced that the main reasons for false smoke warnings are due to the insufficient signal processing/confirmation applied in some types of smoke detectors and/or the maximum allowed detection time of 60 seconds. If the maximum allowed detection time could be changed to e.g. 120 seconds then a significant step in false smoke alarm reduction could be made. [7]

5. Smoke Detector Requirements

The function of the equipment is to detect emerging smoke and thus to detect an arising fire. Any compensation/filtering process shall not degrade the equipment´s ability to detect smoke.

5.1 Smoke Detection Performance

With reference to EN54-9 [8]"Methods of test of sensitivity to fire", the equipment shall at least detect the test fires TF2 to TF5 within the range given in that document.

Normal operating conditions

Temperature range –40 to 86 degree Celsius

Pressure range 1089 mbar abs to 571.8 mbar abs

Depending on the sensor's measurement principle it may be necessary to justify the ability of the equipment to detect smoke/fire in the a.m. temperature and pressure ranges. For further environmental conditions refer to the chapter Qualification Test.

The equipment shall be tested by application of an appropriate test stimulus, e. g. air containing smoke having a light obscuration value of 3% per meter. For equipment in which the sensitivity and/ or response time is affected by any factors which may be varied from one installation to another tests shall be conducted with the least sensitive and longest response time condition to be used.

Open-area/Point type smoke detector (e.g. cargo/lavatory): The equipment shall be tested with an air sample as defined above which is introduced into the equipment under standard atmospheric conditions. The equipment shall then actuate a smoke alarm within a maximum time period of 30 seconds.

Flow-through/Duct type smoke detector (e.g. avionics): The equipment shall be operated continuously by varying the pressure differential from 25% below to 25% above the rated. This pressure variation shall have no influence on the smoke detection performance.

Development smoke tests shall be carried out by the supplier to define a good compromise between adjustment of the electrical alarm threshold and the housing layout to get an acceptable response time (target within 20 seconds) if the equipment is exposed

to a fire. The final sensitivity adjustment shall be recommended by the supplier and agreed with the aircraft manufacturer.

The equipment shall not revert to „no smoke“ signal condition following an alarm indication when held immersed in smoke levels at least 25% greater than the „Smoke-“ response level for the equipment for a period of ten hours.

The equipment shall revert to a „no smoke“ signal condition when the smoke level is reduced to approximately 50% of the „Smoke-“ response level.

The equipment shall include means to avoid/compensate effects caused by environmental condition changes such as e.g. temperature, altitude, acceleration and possible combinations of those parameters.

The sensitivity drift due to temperature/pressure changes and component tolerances shall not exceed +/- 15% of the corresponding thresholds. The measurement of the response threshold value shall be carried out in a manner as described in EN54-7 annex B.

With reduced tolerances (see above) following EN54-7 tests are applicable:

Repeatability	Refer	to	EN54-7	clause	6.
Directional dependence	Refer	to	EN54-7	clause	7
Reproducibility	Refer	to	EN54-7	clause	8.
Air movement	Refer	to	EN54-7	clause	10
Ambient Light	Refer to EN54-7 clause 12				

Hermeticity of Flow-through/ Duct detector:

The leakage rate shall not produce a pressure variation inside the smoke detector more than typically 5 mbar (max. 7 mbar) after 60 sec. With the equipment being exposed to an internal pressure equal to the external pressure minus 20 mbar at the beginning of the test. This test has to be applied on each unit.

Fire Resistance of open-area/ point type smoke detector:

The equipment shall be able to withstand the effect of an open fire at 232,2 degrees C (450

degrees F) for 1 min. Smoke shall be indicated during test for at least 20 sec. Installation in designated fire zones is not permitted.

5.2 Fatigue Test

Detector forced to smoke / standby conditions.

The purpose of this test is to demonstrate that the item of equipment will retain its proper characteristics when subjected to repeated tests.

A minimum of 120000 cycles shall be performed. Each cycle shall last one minute and consists of:

- 20 seconds alarm
- 40 seconds standby

The test shall be carried out under ambient temperature and pressure conditions. For the purpose of test runtime reduction up to 10 smoke detectors may be interfaced.

Detector-power-up-test (Reason: System may not be energized if the aircraft is parked)

The purpose of this test is to demonstrate that the item of equipment will retain its proper characteristic when subjected to power up.

Cycle type 1	Cycle type 2
Power-on time of 2 minutes or more Power-off time of 2 to 3 seconds	Power-on time of 2 minutes or more Power-off time of 5 minutes

- A minimum of 30000 cycles (type 1 and type 2) shall be performed.
- The number of each cycle applied shall be equal.
- Cycle type 2 sequence shall follow cycle type 1 sequence

It shall be verified during each test cycle that the smoke detector does neither emit a detector “Fault“, “Alarm“, nor any other failure.

The test shall be carried out under ambient temperature and pressure conditions.

6. Environmental Conditions and Test Requirements Associated to Qualification

The environmental conditions applicable to airborne equipment are largely different compared to industrial or maritime applications [9]. It is of great importance to qualify the detection performances of a fire/smoke detection instrument in an approved laboratory prior to it is release to qualification tests.

The Airborne smoke detectors to be used in Airbus shall comply with the environmental conditions and test procedures as defined in document RTCA/DO-160 [10], and ABD0100. [11], completed by the requirements contained in EN54-7 [12].

During the environmental tests, the tested smoke detector shall not:

- generate a smoke warning signal
- become inoperative
- generate a fault signal

The applicable tests and their category are defined in the technical specification to be issued by the aircraft manufacturer for each equipment/system.

7. Equipment Specific Software Requirements

Software shall be produced in accordance with the definition contained in RTCA /DO-178 [13]. The software level will be identified by the System Safety Process [14]. For example Level B could be assigned to cargo compt application and Level C for lavatory application. Software partitioning is required whenever different software levels are used within an equipment.

8. Certification Aspects

The smoke detection equipment/systems will be certified together with the certification of the aircraft following the aircraft type certification process or supplementary type certification procedures when applied after type certification.

To achieve certification the suppliers have to provide the aircraft manufacturer with all product relevant justifications to demonstrate compliance with the applicable airworthiness regulations. The fire/smoke detection performances of the fire/smoke detection instrument must be proven by the supplier during equipment qualification phase. These justifications will be added to those ones which have to be established by the aircraft manufacturer.

The purpose of the smoke detection test in the aircraft is only to verify that smoke generated at the most unfavourable place in a compartment will reach the approved fire/smoke detection instrument and actuate an alarm within the required time frame. Thus to demonstrate compliance with JAR/FAR 25.858 (a) for example in case of a cargo compartment.

9. Summary

An early detection of an in-flight fire/smoke situation is mandatory to initiate the corrective action at an appropriate time, but false warnings could be critical as well.

Investigations showed that the problem to safely detect a fire/smoke situation and to distinguish this from all non-fire/smoke situations is not yet fully solved in the pressurized areas of transport aircraft.

Further improvements are very limited as long as the 60 seconds detection time requirement (ref. JAR/FAR 25.858) must be fulfilled to certify fire/smoke detection systems.

10. References

[1] Joint Aviation Requirements, JAR-25, Large Aeroplanes, Change 14, 27May 1994, JAA, Hoofddorp, The Netherlands

[2] Federal Aviation Requirements, FAR part 25 incl. Amendments 1-98

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[4] Joint/Technical Standard Order JTSO/TSO-C1c, Cargo Compartment Fire Detection Instruments", 10.June 1991

[5] Freiling, A, New Approaches to Aircraft Fire Protection, see this book of conference

[6] Blake, D. FAA Technical Centre, Fire Safety Section, Report No DOT/FAA/AR-TN0029, June 2000

[7] Schmoetzer, K. "Improvement of Smoke Warning Reliability in Aircraft Application", International Aircraft Systems Fire Protection Working Group Meeting, May 2000, Atlantic Hotel, Bremen, Germany

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[10] Radio Technical Commission for Aeronautics (RTCA) Washington D.C., RTCA/Do-160D Environmental Conditions and Test Procedures for Airborne Equipment

[11] Airbus Directives (ABD) and Procedures, ABD0100-Equipment-Design, General Requirements For Suppliers, Issue C, December 1998.

[12] EN 54-7 Components of automatic fire detection systems Part 7 Specification for point-type smoke detectors

[13] Radio Technical Commission for Aeronautics (RTCA) Washington D.C., RTCA/Do-178B Software Considerisations in Airborne Systems and Equipment Certification

[14] Airbus Directives (ABD) and Procedures, ABD0200-Requirements and Guidelines for the System Designer, Issue C, December 1998.